Flora W. Patterson

THE STATE COLLEGE OF WASHINGTON

THE AGRICULTURAL

EXPERIMENT STATION

PULLMAN, WASHINGTON.

IMPERIAL BUREAU OF MYCOLOGY
13 JUL. 1921

Bulletin No. 83

DEPARTMENT OF AGRICULTURE

Some Important Plant Diseases of Washington

By W. H. LAWRENCE

1907

All bulletins of this station sent free to citizens of the state on application to the Director.

ALLEN BROS., PRINTERS, PULLMAN.

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Some Important Plant Diseases of Washington

By W. H. Lawrence

With the increase of the various agricultural industries throughout the state there has been an increasing demand for the dissemination of knowledge concerning the more destructive plant diseases. In the meantime other plant diseases of economic importance have found an introduction. A number of these have caused more or less damage in other states. They will probably become abundant enough and so widely distributed in this section as to cause much loss if correct methods of combatting them are not followed closely. To combat these diseases most successfully one must know something of the mode of life of the parasites which cause them. It is important to know the length of time that they will live, and whether the organisms live on the outside or are imbedded in the body of the host. Other points to be considered are the number of spore forms matured, the approximate date of their maturity, the time they are set free, and when they will germinate. It is the purpose of this bulletin to give the necessary information concerning some of the more important diseases which will enable any person to combat them by the best known methods. Of the number considered Club Root of Cabbage, the Crown Gall Diseases and Fire Blight of the Pear are the only ones mentioned that are caused by organisms other than fungi. These organisms are only mentioned in connection with the discussion of these diseases. The fungi that cause the remainder of the diseases discussed are so similar that a general discussion is given concerning them.

FUNGI.

Fungi are low forms of plant life. Many of them are so small that we cannot see them with the naked eye. Others are much larger and are represented by such plants as toadstools,

mushrooms, puffballs and shelf fungi. These fungi, from the smallest to the largest, are found in various places, growing on all sorts of animal and vegetable matter. They range in color from colorless through white to black, but are never a green color. The color in green plants is due to a substance called chlorophyll. Only those plants that contain this coloring matter are able to manufacture starchy food material from the water and air. As fungi do not contain chlorophyll they are unable to prepare this food for themselves. They must take it in an organized condition. Some fungi procure the food they need from decaying matter—these we call saprophytes. Other fungi take their food from living organisms—these we term parasites. Still others live a part of the time as saprophytes and a part as parasites. It is the forms that live a part or all of their life as parasites in which we are particularly interested.

There is such a difference in the general appearance of these forms of fungi that one naturally concludes that they have nothing in common. Notwithstanding the great differences in general appearance that often exist there is a close similarity in their structure. The greater number of them consist of two parts—the mycelium and the organs of reproduction. The mycelium is the vegetative part. It is usually composed of numerous thread-like branches called hyphae (singular hypha). The hyphae perform the office of manufacturing non-starchy food material. They also collect the substances used for food unless this work is done by special sucking organs called haustoria. These hyphae may grow on the outside of the host and are held in place by the haustoria. In a majority of cases, however, they are buried in the body of the host. The length of time that they may live varies with the species. Some forms live two or more seasons but in a majority of cases they live but a single season. The presence of the hyphae in the body of a plant is usually soon apparent, as they have some definite effect on the tissues. The difference is usually quite different for each fungus.

The fungus which causes blackspot canker kills the infested tissues and they become dry, shrunken and discolored. The one inducing Root Rot causes the decay of the infested roots. The

Apple Scab fungus arrests the growth of infested parts as do the fungi causing the powdery mildews. The Peach-leaf Curl fungus causes the tissues to become swollen.

At some time during the growth of the mycelium spores are usually formed upon it. Some fungi have only a single spore form while others have two or more. These spores are of two types commonly called summer spores and winter spores. The summer spores are, as a rule, rather delicate and mature in a very short time. When set free they will germinate at once. If they come in contact with the host they will cause it to become diseased. These spores serve to spread the fungus during the growing season of the host. The powdery milder fungi and Apple Scab fungus produce several crops of these summer spores each season. The winter spores are usually formed late in the season and are enclosed in receptacles which are either buried in the tissues of the host plant or seated on the surface of some part of it. These spores remain in the receptacles until the following spring when they are set free at the proper time. Some of them lodge on the host and thus cause the disease to appear again. Some fungi that do not form winter spores have a mycelium that lives through the winter. In other cases when but one kind of spore form is produced the spores retain their vitality until the following season of the host thus insuring the perpetuation of the disease. There is so much variation in the round of life in fungi that hardly two forms make the same growth. Owing to the great differences which exist the round of life of each fungus mentioned is given under the discussion of the plant disease which it causes.

CLUB-ROOT OF CABBAGE.

(Plasmodiophora brassicae Woronin).

Club root is a very curious disease of various varieties of plants that belong to the Mustard family. Cabbage, cauliflower, shepherd's purse and hedge mustard are the plants on which it has been collected in this state. Brussels sprouts, garden kale, turnip, rutabaga and radish are also given as hosts in experiment station literature from other stations.

The organism that causes club root is one of the simplest. It

FIGURE I—A badly clubbed root of a cabbage plant. The swollen areas in the branches contain the parasites which later produce vast numbers of spores. The spores are set free when the roots decay. Photographed by Prof. H. S. Davis.

lives in the cells of the roots for a time in which place, at a later date, a large number of spores are formed. The spores are set free when the roots decay. They remain in the soil until conditions are favorable for germination when they germinate their walls, break open, and small, colorless bodies crawl out. These little bodies move about in the soil. If they come in contact with the roots of any of the above mentioned plants they have the power of entering them. Their presence so irritates the tissues that the roots become much swollen and knotty. If there is an abundance of the spores of the parasite in the soil many of the roots of young plants may show signs of the disease in the course of a few days. After the plants have once become infested the disease progresses rapidly. Diseased portions of roots decay in a very short time thus setting thousands of spores free. These spores in turn germinate and the organisms come in contact with other roots and enter them. In this manner the entire root system may soon become badly distorted. With the root system in so diseased a condition the plant is no longer able to grow. This is particularly true when the plants are small at the time infection takes place. Slightly infested plants or those that become infested late in the season may continue to grow but form little or no head. When plants become badly infested and conditions are such that the infested roots decay rapidly the entire crop may succumb in a very short time. Infested plants are recognized in the field by their stunted appearance and by examining the roots for the large knots on them. Also in dry, hot weather the badly diseased plants wilt quickly.

To combat the disease all infested plants should be gathered and burned. Do not throw these plants in a compost heap and then use the same for a mulch as this will not kill the spores. It is an excellent way to spread the organism over a greater area of land. The plants may also be destroyed by burying them deep beneath the surface of the soil if they cannot be destroyed conveniently by burning. One gardener in this state endeavored to get rid of the disease by feeding the diseased plants to stock. The yard in which the cattle were kept was plowed up and planted to garden truck a couple of years later. A part was planted to cabbage. The cabbage was attacked by the organism, which was

still alive in the soil, and the crop was a failure. The spores are not killed when eaten by stock. If the plants are to be fed they must first be boiled to kill the spores.

When the organism has once been introduced in a piece of ground it may continue to live there for 3 or 4 years even when grown to a crop that it will not attack. The only method of getting rid of the club root parasite is to rotate the crops, planting the ground to some crop that is not susceptible to the disease for a period of not less than the time mentioned above. All weeds that belong to the mustard family must be suppressed in the meantime. If allowed to grow the disease will continue on the roots of these plants year after year and when the ground is again planted to cabbage the crop will become diseased. Ground known to contain the organism should be plowed six or more inches in depth to bury the spores as deeply as possible. Deep plowing aids much in their destruction.

Since the disease has found an introduction into the state every one raising garden vegetables should be on the watch for the disease and take steps to eradicate it at once, should it appear.

CROWN GALL OR ROOT GALL.

Crown gall diseases occur on the apple, blackberry, cherry, grape, hop, peach, pear, plum, prune, raspberry and rose in this state. The almond, apricot, ash, chestnut, oak, poplar, quince, walnut and willow are infested with the same diseases in other states.

The galls are easily recognized by their shape and general appearance. The swellings are usually nearly spherical and have a warty surface. They vary in size from as small as a pin to several inches in diameter. They are generally less than two inches in diameter. Little is known concerning the cause of the diseases or the methods of preventing them. Since the different forms vary considerably some notes of interest are given relative to the different forms. These notes include the possible relationship of the different forms and also the communicability of the disease from plant to plant.

The disease on the ash, chestnut, oak, poplar, walnut and willow are interesting from a scientific standpoint, but as they are not known to occur in this state no further mention will be made concerning them.

ON THE ALMOND, APRICOT, PEACH, PLUM, CHERRY, AND RASPBERRY.

Raspberry and Peach.—In an experiment conducted by Halstead, Rep. Bot. Dept. N. J. Agr. Exp. Sta. 1896, 414, it is shown that peach seedlings grown in soil containing minced peach galls are very susceptible to the disease. He concludes from results obtained from the same series of experiments by growing raspberry plants in soil containing minced peach galls that the crown gall diseases on these two plants are distinct. Experiments conducted by Selby, Bull. Ohio Agr. Exp. Sta. 92, p. 214, in growing healthy peach trees in a plot of ground where raspberry plants badly infested with crown gall had been growing, strongly indicates that the disease is the same and can be communicated from the raspberry to the peach.

Almond, Apricot and Peach.—A series of inoculation experiments carried out by Prof. J. W. Toumey, Bull. Ariz. Agr. Exp. Sta. 33, p. 32, 13 Ap. 1900, show that the crown gall of the almond, apricot and peach is easily communicated from the almond to the peach and apricot by both soil inoculations and by placing bits of the galls in incisions made in the bark. He also discovered that the disease is caused by a slime mould which he named Dendrophagus globosus.

Peach, Plum, Cherry, Raspberry, Almond and Apricot.—Mr. G. G. Hedgecock states in his article Science, N. S., Vol. XXII., No. 552, p. 120-121, Jl. 28, 1905, on Some of the Results of Three Years' Experiments With Crown Gall:

"The crown galls of the peach, plum, cherry, raspberry, almond and apricot have been proven by careful experiments with seedlings of each grown from sterilized seed in sterilized soil, watered with sterilized water to be one and the same disease on each of these plants. Peach and raspberry are most susceptible to wound inoculations but also become diseased in infested soil without artificial wounds being made. This disease has not been contagious on the apple, pear and quince.

ON THE APPLE, PEAR AND QUINCE.

Some important information concerning the disease of these plants has been given by Hedgecock. The following is quoted from a reprint from Science, N. S., Vol. XXII., No. 552, p. 120-121, Jl. 28, 1905:

"Careful experiments with apple, quince and pear seedlings raised from sterilized seed in sterilized soil, watered with sterilized water, indicate strongly that both the apple and pear crown gall of the ordinary hard type, the one devoid of numerous side roots or hairy roots is not contagious. These seedlings of apple, pear and quince inoculated with insertions of live apple and pear galls beneath the bark and wood of the roots, and also with minced galls in the soil, remained free from the disease in both the control and inoculated portions of two years' experiments. Carefully selected apple seedlings grown in the nursery were inoculated both in the green house and in field plots. In the experiments for two years the average results from such inoculations was ten per cent. of diseased plants in the inoculated portion and fifteen per cent. in the control portions of the plot. All galls were counted, whether located on the plant at the point of inoculation or not. Extensive inoculation of apple root grafts in the field for two years gives an average of 27 per cent. of plants with galls in inoculated and control portions of the plots. About 10,000 apple trees were used in the above set of experiments."

ON THE APPLE.

There are two diseases of the apple which are known as crown gall and hairy root. Some contend that they are distinct diseases, others that both are forms of the same one.

Crown Gall.—The galls may appear on the stem and roots but are usually located on the crown. Infested trees seldom show signs of injury and may live as long as healthy ones. Since there is much evidence that the disease is not contagious, or only slightly so, trees that are making a good growth or that are bearing paying crops should be allowed to stand. However this does not apply to nursery stock. Much nursery stock is sold that is infested with crown gall. All such stock should be burned. The orchardist cannot afford to plant any but the healthiest of stock. The best

FIGURE II—Two young apple trees badly infested with crown gall. Photographed by Prof. H. S. Davis.

is none too good. Removing the galls before planting is sometimes practiced. This is a loss of time and labor as the galls will appear again. Do not plant any but apparently healthy stock.

The same arguments are applicable to the crown gall of the pear.

Hairy Root.—The trouble known as hairy root is easily distinguished by the absence of large branch roots and by numerous small roots growing in bunches on the sides of the main root. It occurs on seedlings as well as on both grafted and budded stock. The disease is probably distinct from crown gall as no signs of galls are present on some plants infested with hairy root. It is held by some that galls will appear in the neighborhood of the roots at a later date. This is a disputed point. The mere fact that it may or may not be a form of crown gall is of little concern to the tree planter. The question with him is the value of the stock in making an orchard. Stock infested with hairy roots will produce a very poor root system and should be discarded with as much care as when infested with crown gall.

ON THE GRAPE.

The crown gall of the grape is slightly contagious. In planting a vineyard it is best to discard all plants that show signs of the disease. If the disease appears at a later date prune and burn the infested parts.

FIGURE III—A short branch of a grape vine infested with crown gall. Photographed by Mr. A. L. Melander

ON THE HOP.

The crown gall of the hop has not done a great deal of damage up to this time but it is becoming more abundant. In pruning the galls should be removed from the roots and crown of the plant and destroyed by burning or buried some little distance below the

surface of the ground in some out of the way place. They should never be allowed to remain in the field as the galls contain parasites which when set free by the decaying of the galls will find their way to the plants and cause new galls to appear.

FIGURE IV—A badly infected hop root. The large gall had completely girdled the stem and the leaves had become a light yellow color. Photo by Prof. A. L. Melander.

ON THE BLACKBERRY.

The disease of the blackberry which is known as crown gall or cane knot is contagious as shown by a number of inoculation experiments conducted in the field. It is very destructive in some years, especially on the Snoyder variety. The Kittatinny and Himalaya Giant are also occasionally badly infested. Other varieties, as the Erie and Early Harvest, are damaged to a slight degree. The Evergreen is only very slightly susceptible.

Small galls were taken from the last named varieties on two or three occasions in the summers of 1902 and 1903.

Galls may appear on canes of both seasons' growth. They seldom occur on canes of the current year's growth unless they have been injured in cultivating and training. Knots may appear at any time during the season. Knots on the old canes begin to appear by the middle of May in most cases. Growth continues throughout the season but the greater amount takes place in the spring just before to a little after flowering time.

FIGURE V—A two-year-old Snyder Blackberry badly infested with crown gall at the collar. Galls on the crowns are rare. Photo by Fred True.

The disease seldom attacks the crown of the plant. A majority of the knots are found on the main stem on the lower portion. Badly infested ones may be literally plastered with knots from the crown to the leaves. Galls have frequently been seen on the stalks of leaves and on a few occasions on the ribs of the leaves.

The injury done depends on the location of the knots. They may occur in the pith, in the wood or in the bark. When the disease is abundant they seem to be pretty well distributed throughout all the parts. As the knots mature their influence on the stem and fruit is quite marked. Galls near the center of the stem cause them to split open. Occasionally canes are split the

greater part of their length. Those under laterals will cause the branches to break off. Those int he bark and wood also cause a greater or less splitting of the tissues. Galls that appear in the crotches of the branches frequently girdle them. The pressure exerted may also cause the lateral to split in the angle between stem and branch.

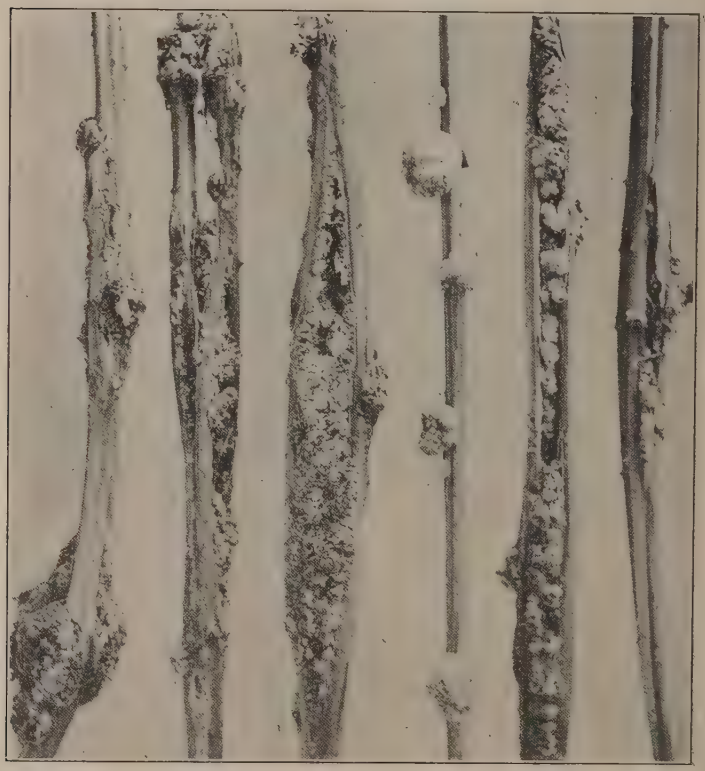

FIGURE VI—Two-year-old canes of Snyder blackberry showing the effect of crown gall. When the galls begins to develop in the pith or wood they cause the cases to split open. When infection takes place in the bark the galls are nearly round. Photo by M. D. True.

Since the warts mature in size soon after flowering it is not uncommon to see whole branches laden with partially developed fruit beginning to wilt. More often, however, the fruit matures fairly well in size but it is dry and tasteless and of little value as a food.

The only remedy for this disease is to remove all infested canes soon after the fruit has been gathered and burn them. The parasite that causes the trouble is in the galls and if the galls are allowed to remain in the field they will decay and set the organisms free thus aiding in the spread of the disease. Practice clean culture.

In setting out new yards the stock used should be taken from a field in which the disease has not found an introduction. By so doing a perfectly healthy field will be the result. The disease will not appear unless the organisms that cause the trouble are present. If the stock used in planting new yards is taken from a diseased field even if only those plants are used which do not show signs of the galls the trouble will be quite sure to manifest itself at a later period. The writer has seen this occur in a number of instances.

ON THE RASPBERRY.

In some sections the same disease that occurs on the blackberry is also found on the raspberry. It does not do nearly as much damage as on the latter host. Galls only occur on the stem above the ground. There is also a second form of crown gall of the raspberry that occurs in localities in which the former has not found an introduction. This form grows on the roots and crowns and causes a great deal of injury. Plants infested with this form were so badly overcome that they were dug up and burned.

FIGURE VII—Two raspberry canes badly infested with crown gall. This disease was introduced on nursery stock and is apparently very destructive as the galls appear on both the lower end of the stem and the roots. Photo by Prof. H. S. Davis.

FIRE BLIGHT OR PEAR BLIGHT.

(Bacillus amylovorus Burrill.)

Fire Blight or Pear Blight is a contagious bacterial disease of pears, apples and other pomaceous fruits. As a general rule pears are the most susceptible.

The disease makes its appearance in the spring when the trees are in bloom. The bacteria which cause the disease live and multiply in the nectar of the flower. Bees and other honey and pollen collecting insects in visiting the flowers carry the bacteria from flower to flower. In this manner a few or nearly all the flowers on a tree may become infested. This is especially true if infection takes place when the flowers first open. Besides attacking the flowers the bacteria may also enter the tips of young growing shoots. The bacteria work their way from the flowers downward into the young spurs and twigs and in some cases even down into the main branches and trunk. Occasionally the stalks and ribs of leaves are also attacked.

Near the close of the blooming period infested flowers appear as if they had been killed by frost. They soon dry up. Infested twigs and branches become very dark colored and die. The leaves on these branches turn brown but do not fall for some time, thus making the branches very conspicuous. Larger branches may also die because of the bacteria working down a lateral shoot and girdling the brand thus causing the death of the parts above the girdle. If the disease is severe enough to run down into the bark on the larger limbs and trunk the entire tree may succumb.

The greatest amount of damage is done during the first six to eight weeks following the time of infection. After this time the rate of spread depends largely on weather conditions. The disease is most active during moist, warm weather but will spread slowly during moist, cool weather. Dry, hot weather prevents further spread. Under the most favorable conditions the disease may spread a foot or more in a day. It usually travels an inch or so in a day.

When the disease has quit spreading there is a very sharp line between the infested and healthy tissues. If it is still progressing there is a gradual blending of the color between the healthy and

infested portions. This change is so gradual that it is very difficult to tell just how far the disease has progressed. By the close of the growing season nearly all the bacteria in the diseased tissues are dead. In a few areas, however, they continue to penetrate farther into the tissues. It is in this manner that some of them live during the winter. When the tree becomes active in spring the bacteria that have kept up a slow growth during the winter begin to grow at a much more rapid pace. The moist, warm weather at blooming time is the ideal condition for a very marked activity. In many cases gum exudes from these diseased areas and runs down the outside of the bark. There are many bacteria in this gum. Insects feed on this gum as well as on the nectar and pollen. Bacteria are thus carried from the gum to the flowers and some of them lodge in the nectar in which substance they are known to thrive and multiply. Insects in feeding on the nectar carry the bacteria from one flower to another. A few insects could scatter the disease over a good sized orchard in a very few days. It is easily seen how the greater number of the flowers may become diseased during the blooming period. From the flowers the bacteria grow down into the fruiting spurs and young twigs as explained above.

Owing to the nature of the disease it is one of the most difficult to combat. Since the bacteria that cause the spread of the disease in spring winter in the limbs and twigs of the tree it follows that the only way to prevent the spread of the disease in spring is to cut out all the diseased parts of the tree and burn them in order to destroy the bacteria. If this is done and is done thoroughly there will be no bacteria left to cause a further spread and consequently no more blight. The difficulty in eradicating the disease lies in the fact that some of the diseased parts are overlooked when the work is done and as a result the disease spreads more or less during the following season.

During the fall and winter all dead branches should be removed and burned. If the disease makes its appearance in the spring all diseased twigs and branches should be cut off several inches below the point where the tissues are in the least discolored. If the knife passes through a diseased area it will carry bacteria

with it. Should the knife then be used in cutting healthy tissues it will cause them to become infested with the blight. To prevent this occurring some recommend dipping the pruning shears in carbolic acid after each cut while removing diseased branches. Burn all the prunings. It may be necessary to do this work two or more times during a season that the blight is particularly destructive. Trees that are making the best growth suffer most. The spread in an orchard can be decreased under some conditions. If trees on irrigated land become infected they should not receive more water than enough to keep them alive until the weather becomes hot. Infested trees on soil that is given clean cultivation to preserve soil moisture should not be cultivated until the disease quits spreading. Pruning should be practiced as little as possible in a healthy orchard since it has a tendency toward the formation of new wood which is particularly susceptible.

LATE BLIGHT OF POTATOES.

(Pytopthora infestans DeBary.)

The fungus that causes late blight of the potato plant lives in the leaves of the plant during the summer. When ready to form spores branches project through the breathing pores on the under surface of the leaves and bear spore on their tips. Later they branch and more spores are borne on these branches. The spores will germinate at once. They may produce mycelia which enter the leaves or if the weather is moist and warm each spore gives rise to a number of small spores which swim about for a time in the film of water on the surfaces of the leaves then come to rest. In a very short time these spores will germinate and produce mycelian which penetrate the leaves as stated above. It is easily seen, from the way in which the spores develop, the reason why the disease spreads so rapidly during "muggy" weather—it is on account of the production of so many secondary spores which have the power of swimming about and later coming to rest and forming mycelia. The mycelia in the leaves soon produce the branches on the under surfaces of the leaves and

these in turn produce spores which spread the disease more widely. If the weather is "muggy" it only takes a very short time to mature a crop of spores. The number that might be produced in a few weeks could not be calculated.

The branches which make their appearance on the under surface of the leaves and bear the spores are so numerous that they form white tufts in some cases. Within a few days after the fungus has appeared in considerable abundance the infested parts of the leaves turn brown and die. Later the entire top of the plant may succumb depending on the ravages of the disease. The fungus in the leaves grows down the stem and in some cases penetrates as far as the tubers which it also enters. The diseased portion of the tuber in time turns a brown or black color. It is in the tubers that the fungus passes the winter. If these tubers are used for seed the mycelium works it way up to the leaves and a new crop of spores are produced to spread the fungus during the growing season. If weather conditions are adverse to the development of the fungus the disease may not become abundant enough to indicate its presence. This might continue through two or more seasons and then with a change of climatic conditions an epidemic occur.

Since the disease is apt to occur quite regularly in sections where the disease occurs, spraying should become a regular practice as a part of the care of the crop. In case of an occasional attack the use of sprays each year would probably pay but little for the trouble and expense of making the applications. In case the disease did appear the vines should be sprayed at once. Bordeaux mixture is the best fungicide to use in combatting it. Since the spores are borne on stalks on the under surface of a leaf it follows that the spray must be so directed as to strike the lower surfaces. The best time to spray depends upon weather conditions. The vines should be sprayed as soon as possible after a period of muggy weather, if such weather conditions are present early in the season. The disease usually appears late in June or in July. To catch the early stages spray about the middle of June and every two to three weeks thereafter. Make the applications often enough to keep the leaves well protected so as to prevent the

FIGURE VII½—Leaves of peach infested with peach leaf curl fungus. They are convoluted and hummocky. The mid rib does not elongate as the tissues of the blade become convoluted, thus acting like a puckering string. Photo by Prof. H. S. Davis.

germination of the spores and thus prevent the spread of the disease.

In planting potatoes in spring seed should not be taken from a diseased lot if other seed is available, if not, the seed should be carefully examined and all tubers that show signs of decay discarded. It is best as far as possible to plant the new patch on land that has not been into this crop if diseased the previous year. Plant clean seed on clean soil and practice clean culture.

PEACH LEAF CURL.

(Exoascus deformans Fuckel.)

Peach leaf curl is caused by a fungus that lives in the leaves. It was formerly supposed that the mycelium is perrenial and that it lives over winter in the buds and young twigs. Infection from this source is probably very slight. Infection takes place from spores early in the spring at the time the leaf buds begin to open and later. After the fungus has entered the leaves the blades of badly infested ones become very thick, leathery and at the same time becoming markedly convoluted and hummocky. The lesser infested ones are distorted in a similar manner but to a less degree. A greater number of the badly infested ones usually fall off in a very short time. Occasionally the disease is so abundant that the trees are nearly defoliated by the time the fruit is beginning to form. This causes the trees to grow a new set of leaves at the expense of the fruit crop. On trees that become destitute of foliage a greater portion of the fruit may fall off so that the crop is a light one or a total failure.

As peach leaf curl occurs in nearly every peach growing district numerous experiments have been carried out to find the best possible preventive. Both the sulphur-lime wash and Bordeaux mixture have given good satisfaction. Since infection of the trees takes place from spores in early spring just at the time the leaf buds swell it is evident that the trees must be sprayed while the buds are yet in a dormant condition. The work should be done one to three weeks previous to this time. In making the applications the trees should be sprayed thoroughly so that the entire

surface is coated. The work should be done at a time of day that the trees are perfectly dry so that the spray will not run off. One application is sufficient if the weather remains dry. In case of rain two or more applications may be necessary to keep the trees properly protected. In case of two or more sprayings it has been the experience of experimenters that they will do the most good if all are applied before the leaf-buds open.

WITCHES BROOM OF CHERRY.

(Exoascus cerasi Tuck.)

The fungus which causes this disease is very closely related to the one that causes peach leaf curl. The mycelium lives in the bark and wood of the smaller limbs and twigs. Infested branches and twigs usually become numerous and are more or less elongated and thickened. In some cases the branches become so numerous and grow so long that they are not able to bear their own weight with the result that the broom looks like a weeping branch. The tips of the branches in such brooms usually turn upward. Some of these brooms are large enough and are so conspicuous that they are visible from some little distance at the time of year the leaves are off the trees. They are very conspicuous at blossoming time. Witches brooms bear few if any flowers and the leaves appear on them before they come out on the healthy ones. The leaves that do form on the infested branches are more or less wavy and have a reddish brown tinge. The asci and spores are borne on the under surface of these leaves. The leaves fall off prematurely. Since the brooms do not bear flowers or fruit and they are a source of infection from which other twigs may become diseased they should be cut out and burned at once in order to prevent the development of spore and the distribution of the same. Cut the brooms off several inches below the lowest diseased portion in order to remove all of the mycelium that may extend downward in the bark and wood.

APPLE SCAB.

(Venturia inaequalis Winter.)

This is the most destructive disease of the apple that occurs in the state. The fungus that causes the disease has two stages—

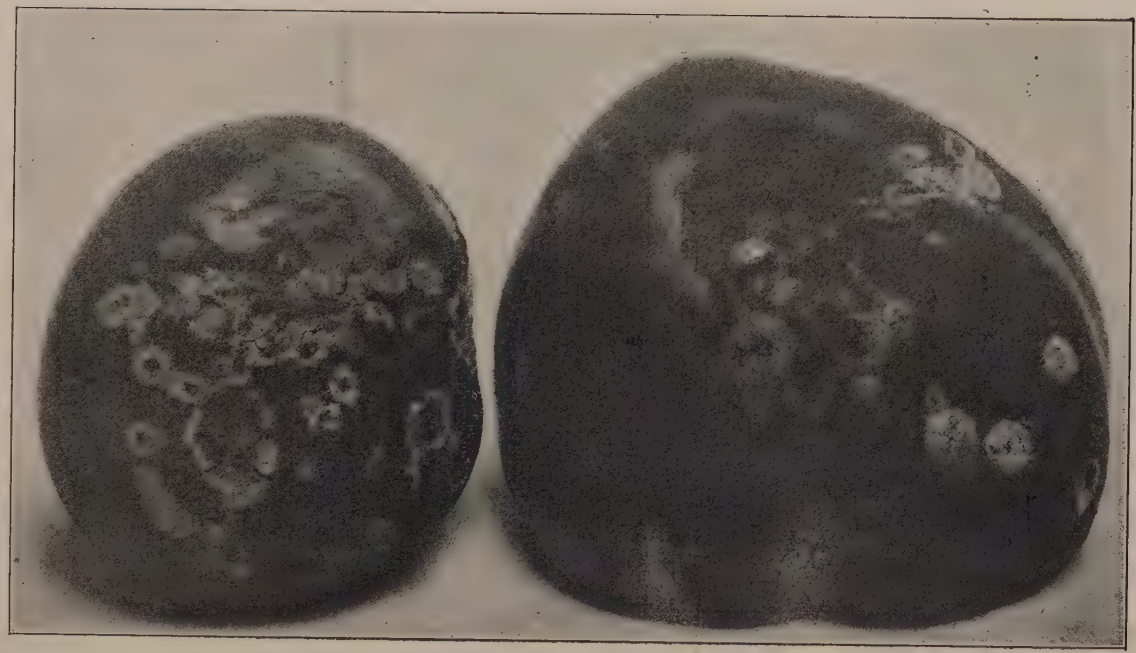

FIGURE VIII—Two Rhode Island Greening apples badly infected with apple scab. The fungus attacked them near the blossom end early in the season, causing them to become misshapen. Several infected spots have become woody and split open. Photo by Mr. A. L. Melander.

the winter stage which lives in the dead and decaying leaves during the winter, and the summer stage which lives on the leaves and fruit during the summer.

The form in the dead leaves continues to grow during the winter. Sometime in late winter or early spring capsules are formed inside the leaves. Each capsule contains numerous spores. About the time the leaves on the apple tree begin to unfurl in spring and later these spores escape from the capsules and float about in the air. Some of them lodge on the leaves, flowers and fruit. If they germinate they will cause the parts to become diseased. The summer stage then makes its appearance in a few days in the shape of small, usually nearly circular dark olive green colored blotches. These blotches are composed of numerous short stalks on the tips of which summer spores are borne. The summer spores mature at once and drop off. If they lodge on the leaves and fruit of the same tree or a neighboring one they will cause new areas to become diseased. Very shortly a second crop of summer spores is produced by the fungus in the new areas which in turn drop off. Some of them are carried by the wind and other agents to the leaves and fruit and thus spread the disease more widely. Summer spores mature in such a short time and are produced in such abundance that thousands of scabby spots appear in the course of a few days when conditions are favorable. As the parts mature the new blotches become less frequent and finally cease to appear. The greater number of them appear during the interval of time between the unfolding of the leaves and a few days after the petals have fallen. The reason that the fungus no longer produces new diseased areas is perhaps due to the epidermis of the leaves becoming somewhat thicker and firmer and thus more resistant so that the fungus is unable to make an entrance.

Since the fungus that causes the disease winters in the dead leaves it is evident that the destruction of as many of the fallen leaves as possible will materially lessen the number of winter spores set free in spring. Plowing the leaves under in the autumn is perhaps the easiest method of getting rid of a greater number of them. This alone will not eradicate the disease. The trees must be sprayed.

Several sprays have been used in combatting apple scab but none have given as good results as properly prepared Bordeaux mixture. Two applications applied on the proper dates are sufficient to hold the disease in check. The first application must be made just before the flower buds open and the second just after the petals have fallen. *

PEAR SCAB.

Pear Scab and Apple Scab are so near alike in general appearance that one easily concludes that the disease on both the pear and apple are caused by the same fungus. These fungi are distinct but are very similar in their structure and life history. Pear scab fungus like apple scab fungus has two stages in its life history—a summer stage and a winter stage. The winter spores are discharged from capsules in the decaying leaves in spring. Some of them are carried to the flowers, leaves and fruit, and cause them to become diseased. The fungus also grows on the young twigs

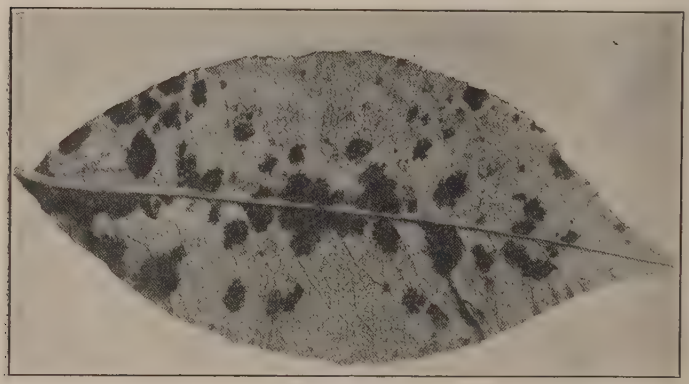

FIGURE IX—A pear leaf showing scabby areas on the lower surface. The spots are dark olive green in color. Photo by Prof. H. S. Davis.

* Recent use of Bordeaux for apple scab has shown that especially in certain varieties and under certain conditions the apples may be russeted by the spray. A study of the causes and prevention of russetting is being made at the Station this season and the results will be reported later—EDITOR.

during the summer. The injury done is about the same as in apple scab.

Since this fungus attacks the same parts of the pear as apple scab does in the apple and at the same dates it can be combatted in the same way by the use of Bordeaux mixture. Spray the trees with properly prepared Bordeaux mixture just before the flower buds open and again after the petals have fallen. Two trees of the Louise Bundy Jersey variety were sprayed with Bordeaux mixture at the Puyallup Experiment Station. The results were as marked as those obtained in spraying trees infested with apple scab fungus.

FIGURE X—A group of pears infested with scab. The fruit is well covered with scabby areas and is more or less misshapen. The fruit has also become woody in some spots and has split open. Photo by M. D. True.

BEAN ANTHRACNOSE.

(Colleototrichum lindemuthianum Briosi & Cavara.)

Bean anthracnose is a disease that attacks various varieties. It was introduced in diseased seed shipped into the state in one case observed. Its introduction in other sections has probably

been the same. If diseased seed is planted a crop of diseased plants will be the result. The fungus which causes the disease is capable of living in stored beans during the winter and again becomes active if the seed is allowed to germinate.

Seedlings grown from diseased seed have diseased areas or ulcers of various sizes on them. The seed leaves, being much larger than the remainder of the plantlet, sometimes have ulcers of considerable size on them by the time the seedlings are well up. Some seedlings are so badly infested that they never appear above the surface of the ground, being too weak to free themselves from the soil. Other plants may appear above the ground and then succumb in a very short time thus leaving a very poor stand. As the plants develop ulcers may appear on any part of them. The nature and the amount of injury done varies greatly. Ulcers may girdle the main stem or some of its branches or attack the leaves and cause them to fall off. The disease may destroy the entire crop in some cases and in others do but little damage. As a rule, however, the amount of injury that is done is usually great enough so that the crop produces but slight returns.

The disease on the blades of the leaves and the remaining portions vary considerable. The disease can best be identified by the appearance of the ulcers on the part of the plant other than the blade of the leaf. On the leaves the ulcers form dark colored spots which shrink up, separate from the living parts by irregular fissures. The ulcers which occur on the stems, branches, stalks of the leaves and later on the pods are quite different and are very characteristic. They first appear as reddish brown specks. As they enlarge they become oblong or more or less irregular in shape by the fusion of two or more young ones. They are also more or less depressed. In the more developed ones the central portion is dark colored but the margin is bordered with a red ring. Shortly after the ulcers are well formed numerous pinkish white masses of spores appear near the center of each. They are arranged in concentric circles. The spores are held together by a jelly-like substance soluble in water. When carried to any other part of the plant they will germinate at once. New cankers may make their appearance at any time during the season from the

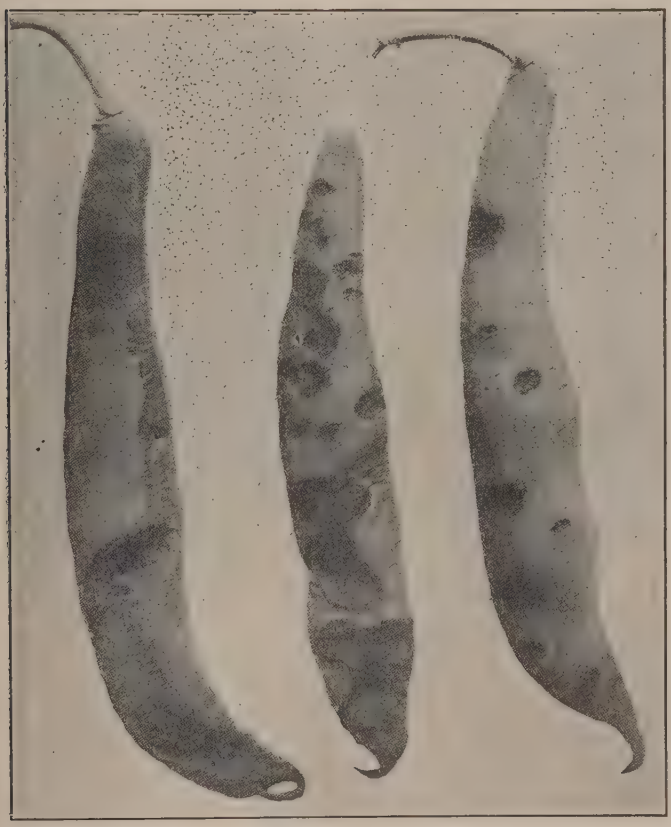

FIGURE XI—Pods of a garden bean showing the ulcers and their effect on them. The margin of each ulcer is bordered by a red ring. The spores of the fungus which causes the ulcers are gelatinous, pink, concentive circles on the surface of the ulcers. Photo by Prof. H. S. Davis.

time the plants come above ground until they become hard and woody.

Later in the season numerous cankers make their appearance on the pods. The fungus penetrates through the pod into the seeds. If infection takes place late in the season or the infection

is only slight this seed will develop enough so that it will germinate the following spring. As a rule the diseased seed is more or less discolored and the badly infested ones may be more or less wrinkled, dotted with blister-like elevations or even pitted. The lesser disease seed is often times planted not knowing that it is diseased. Such seeds are sure to produce a diseased crop.

If the disease makes its appearance the plants should be sprayed with Bordeaux mixture. The applications should be frequent enough to keep the plants well protected during the remainder of the season.

In planting seed be sure to obtain healthy seed if possible. If this cannot be done the seed can be selected from a diseased lot but great care must be taken to discard all the diseased ones or the results are apt to be disastrous. As soon as the plants are up and well under way spray them as directed. All the badly infested plants should be collected and burned from time to time.

BLACKSPOT CANKER.

(Myxosporium curvisporum (Peck) Sacc.)

Blackspot canker is a disease of the apple tree. In importance it ranks next to the apple scab. It is very prevalent and destructive in Western Washington in localities where the rainfall is considerable during the latter part of autumn and early winter. The disease is caused by a parasitic fungus. The fungus lives in the bark for about a year and then dies. Before it dies it forms spores the greater number of which are distributed from October to late December or a little later. These spores are carried about by the wind and some of them lodge on the bark of apple trees. The moderately low temperature and plenty of moisture usually present in November and later are conditions most suitable for germination. On germinating the fungus enters the bark. Occasionally by the end of a week new cankers make their appearance. They are about the size of a pin head circular, somewhat sunken and nearly black. They increase slowly in diameter but the fungus penetrates the bark into the sap wood beneath. When the tree begins to leave out the cankers increase rapidly in diameter and are mature in size by the last of June or a little later.

Mature cankers are usually oblong and vary in size from ¼ of an inch to 6 inches long by ¼ of an inch to 5 inches in width. Frequently they appear to be much larger. As a rule these larger ones are the result of two or more smaller ones merging together. The cankered bark becomes dry and brittle and separates from the living leaving a fissure. It remains on the tree for a time and then falls out leaving a scar.

About the time the cankers are full grown the epidermis on the cankers become slightly roughened by the formation of pustules just beneath it. Each of these pustules contains numerous spores which when disturbed will cause the new cankers to appear.

Since the spread of the disease is caused by spores and the spores germinate in November it follows the way to prevent the disease is to prevent the germination of the spores. This can be done by spraying the trees with double strength Bordeaux mixture about the first of November to kill the spores on the bark. Under ordinary weather conditions there will be sufficient spray on the bark to kill spores that may lodge on it for a short period of time if the work has been done properly. To catch the spores that are distributed later in the season spray a second time with double strength Bordeaux mixture making the application thorough so that the entire tree is covered with the spray. The second spraying should be done two or three weeks after the first. In rainy weather three or more sprayings may be necessary to keep the bark protected.

FIGURE XII—Three main branches of a young Wealthy tree, showing the action of the fungus. The cankers are one and two years old. A portion of the bark in the older cankers has fallen out, leaving the wood exposed. Photo by Prof. H. S. Davis.

POTATO SCAB.

(Oospora scabies Thaxter.)

Potato scab is a very abundant and widely distributed disease. The disease first appears as brown spots on the surface of the tuber, usually in small roughened areas called lenticels. These spots increase in size at a fairly rapid rate. The color becomes darker and the tissues somewhat swollen. The areas are more or less irregular in shape and are scab-like in appearance, so much so that the common name has been taken from it. These areas, in the older stages, frequently become dry and crack open. The fissures may become of considerable depth in some cases.

The injury done depends upon the number of scabby areas and the depth to which the fungus has penetrated that causes them. If infection takes place while the tubers are yet young the disease becomes much deeper seated than if infection takes place at a later date. From the time infection takes place the spots increase in size at a fairly rapid rate. They continue to increase in size even after the potatoes are ripe, especially if they are allowed to remain in the soil. Since this is true, scabby potatoes should be gathered as soon as mature to prevent this later development.

Since potatoe scab frequently does considerable damage and the cost of combatting the disease is so slight that the fungicide can be applied at a very low cost, no one should plant seed that is even slightly infested unless properly treated. The best method of getting rid of the disease is to plant clean seed on clean soil. Select smooth tubers and soak them in a solution of formalin (1 lb. to 30 gallons of water) for two hours. Remove them from the solution and let them drain and then cut them for planting. This will kill the spores of the fungus that may have lodged on the tuber. Be sure before handling the tubers that the knives, pails, sacks, etc., have been further sterilized with boiling water or formalin solution if they have come in contact with diseased potatoes or the spores will lodge on the sections and the results of the treatment unsatisfactory. As stated above planting should be done on clean soil. After the fungus has

become established in the soil it will live through the winter season and if the same land is planted to potatoes the following season some of the new tubers will be scabby. It has been found that the soil may become infested by the application of manure from stock that has been fed with diseased tubers. It is evident that the mycelium or the spores of the fungus are not killed in passing through the digestive tract of animals. If the potatoes are to be fed to stock they should first be boiled to kill the fungus.

CANKER OF SOFT MAPLE.

(Tubercularia vulgaris Tode.)

This disease has recently made its appearance on the soft maple and in a few cases has done considerable damage. Infection of the host evidently takes place in early spring up to the middle of the summer. Numerous leaf and flower buds are killed in spring before they open. Later in the season twigs and larger branches are girdled, some of them succumbing as late as the middle of July. When the cankers first appear the bark is dark colored and shrunken. The wood is also more or less discolored, showing that the fungus penetrates it to a greater or less degree. When girdling of the limbs takes place the leaves begin to roll up and become a light silvery color, due to a lack of sufficient moisture. Shortly the leaves begin to change to a light brown and later to a deep brown, appearing very much as if scorched by fire. These leaves usually remain on the tree for considerable time but finally fall off. About this time the cankers become dotted with small nearly spherical elevations of a pink color about half as large as a pin head. These are masses of spores of the fungus that causes the cankers. To combat this canker disease all the dead and dying limbs should be cut off a few inches below the cankers and burned at once. The pruning should be done before spores are matured in order that further distribution of the fungus will not take place. A little care at frequent intervals will suffice to keep the trouble under control. No sprays have been tried in combatting the disease. One or two thorough sprayings with Bordeaux mixture in spring before the buds open will not do the trees any injury and will undoubtedly kill a greater number of spores that may be present.

FIGURE XIII—Infested twigs of the soft maple. The small round bodies on the twigs are branches of the fungus which bear numerous spores. The spores are imbedded in a gelatinous substance. They are pink in color. Photo by Prof. H. S. Davis.

BROWN ROT OF THE PRUNE, PLUM AND CHERRY.

(Monilia fructigina.)

Brown rot is a disease that is well known in nearly every country in which the prune, plum and cherry are grown. It does a great deal of damage in some sections in this state in some years. It is known to attack the pear and apple in some sections, but to this time the writer has only seen it on the plum, prune and cherry in this part of the country.

The fungus that causes brown rot occasionally makes its appearance on the flowers at blossoming time and later on the young fruit. The disease sometimes appears on green fruit that is only partially developed, but as a rule it does not make its appearance until about the time the fruit begins to change color. In some years only a small amount of the fruit may show the rot at this time and little damage is done. In other years the greater portion may decay in the course of a few days. The damage done depends largely on weather conditions. Moist warm weather is most favorable.

When the rot first makes its appearance on the fruit it shows as a small usually nearly circular area of a dark brown color. After several days' time the area usually becomes large enough so that it involves the greater portion of all the fruit. At the same time the surface of the decaying portions becomes dotted with ashy gray tufts. These tufts appear first near the center of the infected area. They are masses of the spores of the fungus borne on the ends of little stalks. The spores mature rapidly and will germinate at once. If conditions are such that the spores are distributed and the weather is moist and warm so that they will germinate readily the entire crop may be destroyed in the course of a few days. It is impossible to predict what this fungus will do in any season.

When the diseased fruit is well filled with the fungus it becomes dry and hard. A few of them will fall off the tree, but a greater number of them will remain on them as mummies. These mummies are well covered with tufts of the fungus bearing many spores. The interior of each is well filled with the mycelium of the fungus. The mycelium in these mummies evidently lives through the winter and produces more spores the following growing season of the host. It is also known that some of the spores will germinate when more than a year old.

Since the fungus may live through the winter in either or both the above mentioned ways it follows that the first step in combatting the disease is to collect and burn all the mummies that hang on the trees over winter and also all that are lying on the ground at the base of it. Many of the spores that are formed

FIGURE XIV—Mummied cherries. The tufts on the surface of each are masses of short stalks which bear chains of spores. The tufts are ashy-gray in color. Photo by Prof. Davis.

on the mummies lodge on the bark of the tree when set free. In order to kill these spores the trees should be sprayed thoroughly with Bordeaux mixture in early spring before the leaves come out. Trees, the tops of which have dense foliage, should be pruned to open the top in order to admit as much sunlight as possible after the leaves come out. This will allow the rapid evaporation of excessive moisture such as dew and rain. By the time the fruit is partially mature in size the trees should be sprayed a second time with Bordeaux mixture. Shortly before the fruit changes color spray a third time with copper acetate solution. This spray is used in place of the Bordeaux mixture as it does not leave a residue on the fruit. Before making this last application the fruit should be thinned so that it does not touch each other. If weather conditions are favorable for a rapid spread of the disease after the first application of copper acetate

solution has been made two or more subsequent sprayings should be made in order to keep the fruit protected until it is ripe enough to gather.

This disease is a very hard one to control. The same preventives applied under similar conditions have given both satisfactory and unsatisfactory results. Generally the above method has been the most satisfactory and is the one recommended for this section.

DRY ROT OF POTATOES.

(Fusarium oxysporium Schl.)

The fungus that causes this disease attacks the roots and underground stems of the potato plant. It usually makes an entrance into the plant through the roots and then slowly spreads through the root-system into the tubers and lower end of the stem. Diseased plants first become noticeable in midsummer and later after the plants are nearly mature in size. Those attacked some time before they are mature are somewhat dwarfed. Plants attacked late in the season or only slightly infested show little or no signs of injury. Badly infested ones are quite easily recognized by the changes which take place in the leaves and stem. The leaves loose their lustre and become a light yellow color. The blade also curls or rolls up. Occasionally the roots become so badly weakened that they can no longer support the weight of the top and the plant lies prostrate on the ground. One or more plant in a hill may become diseased while others remain perfectly healthy.

At the time the tubers are harvested they seldom show external signs of the disease. If they are cut open lengthwise and examined the diseased ones can be identified by the presence of a cinnamon brown colored area, usually at the stem end. The discoloration extends but a short distance in the flesh and is usually found in the bundle. Other areas may show signs of the disease as the fungus may enter through the basal end or through injuries done in cultivating. The fungus evidently makes very slow progress while the tubers are still young and

growing. Later, when potatoes are mature, this growth is somewhat more rapid. After the potatoes are gathered and placed in storage the fungus continues to grow farther and farther into the flesh, at the same time following the vascular ring. The rapidity with which it progresses depends largely on storage conditions mentioned below. The color in the diseased flesh changes from a reddish brown to almost black with age. The entire vascular bundle and adjacent tissues may become black in color before the signs of decay appear externally. After the decay has advanced to this stage the mycelium grows toward the inside and also outward. The hyphae that push outward finally break through the epidermis and appear as a white growth on the surface. These areas in the meantime become shrunken and almost black in color. This change is particularly marked in the region of the eyes as the hyphae reach the surface at these points first. In the course of time the entire tuber is entirely filled with the mycelium. The flesh shrinks and the skin becomes wrinkled. The flesh becomes darker in color and drier, finally becoming as firm as wood. Some of the potatoes in a lot infested with this fungus may appear as if decaying with a wet rot. This difference is due to the action of bacteria or other fungi which has found an introduction into the already infested areas.

Owing to the nature of the disease it is a very hard one to combat. The method of getting rid of such a disease is to plant clean seed on clean soil. If the fungus has become abundant in the soil the land should not be planted to potatoes for a period of several years as the fungus will live in the soil for a considerable length of time. If potatoes are used for seed that were taken from a field known to contain the fungus they should be carefully examined before planting in order to discard any that might be infested. A superficial examination of the seed is not thorough enough. Cut off the stem end of each potato and note if there is a cinnamon brown colored area present. If such a color is present all of the flesh that is discolored must be discarded. A better plan would be to use none but perfectly sound tubers.

In harvesting a crop of infested potatoes all the vines should be collected and burned. At the time of harvesting a few potatoes

FIGURE XV—Potatoes infested with the dry rot fungus showing the stages of decay after the fungus has penetrated through the epidermis. Photographed by Prof. H. S. Davis.

may be damaged enough so that they are only fit for feeding stock. If they are fed to stock they should be boiled to kill the fungus as it probably is not killed in passing through the digestive tract, if the manure is to be used as a fertilizer in the potato field. If they are to be discarded they should be buried some inches below the surface of the ground—deep enough so that the plow or cultivator would not come in contact with them if buried in the field.

Since the diseased areas in infested potatoes are small at the time of harvesting, the potatoes should be used at once to utilize as great a portion as possible. There is no danger of the fungus injuring a person even if eaten before being boiled. If the potatoes cannot be used at once they should be stored in a cellar and kept as cool as possible. The temperature should be about 40 degrees F. The low temperature will cause the fungus to make a very slow growth.

WHEAT SMUT.

Tilletia tritici Pers.

Wheat smut is the most destructive disease of the wheat plant. Some varieties are more susceptible than others. Little club smuts as badly as any. The disease is caused by a fungus that is parasitic upon the wheat plant. The only part of this fungus that is seen by the wheat grower is the mass of spores inclosed in the skin of a wheat kernel—the so-called smut ball. These spores form the fine black powder which flits about in the air when the smut balls art broken open. In threshing the smut balls are broken open and the spores lodge on the sound kernels of wheat. Some of them find their way in among the tuft of hairs at one end and others lodge in the grove of the kernel. When the wheat grain is planted the smut spores are planted with it. When conditions are favorable for the germination of the wheat the smut spores will also germinate. The smut fungus produces several small colorless spores which in turn produce a considerable of minute smut plants. The young wheat plant and the young smut plants thus grow side by side. One or more of these little smut plants may grow into the wheat plant and

grow up with it. When the wheat plant heads out the fungus grows into the young kernels and uses up all the food furnished for the growth of the grain in forming its spores. When the wheat is ripe the infested kernels consist only of the skin of the kernel filled with smut spores.

The smut fungus only has the power of entering the stalks of wheat plants while the epidermis is still young and tender. The epidermis becomes hard enough by the time the first leaf unfurls so that the fungus cannot enter through it. If the fungus has not made an entrance by this time it will not be able to do so, and there will be no smutted heads of wheat.

If smutted wheat is to be used for seed and a clean crop is desired it follows that the seed must be treated in some manner to kill the smut spores that are on it or to prevent their germination until the wheat plants are old enough so that the fungus cannot enter them. There are several methods of treating the wheat to accomplish the desired results. None has been as satisfactory and has done as complete work as the formalin treatment when the proper method has been followed. The following information concerning formalin and its use in treating smutted grain is quoted from a special bulletin prepared by R. Kent Beattie, Botanist of the Station.

THE FORMALDEHYDE TREATMENT: Formaldehyde, Formalin, and Formalose, are the same thing. Formaldehyde should sell at the drug stores, in pound bottles, for about 50 cents a pound, and a pound will treat 40 to 50 bushels of grain. If properly used it will kill the smut without injuring the wheat.

HOW TO TREAT THE SEED GRAIN—Either method is good:

Sprinkling Method: Clean a floor, or a canvas, if smutty, with scalding water; spread out six or eight bushels of grain; sprinkle it with a solution of one pound of Formaldehyde to 45 gallons of water, by means of a spray pump, a sprinkling can or a broom. While sprinkling, shovel vigorously, and see that every grain is wetted. Throw it aside in a pile, and continue until all is treated. Cover pile with wet sacks for two hours.

Trough Method: Set a large watering trough with one end three or four inches higher than the other. At the lower end, set a barrel. Put in it one pound of Formaldehyde in 45 gallons of water. Pour a half a sack of grain into the lower end of the trough. With a small bucket pour a little of the solution on it. Shovel the grain till every bit of it is wet. Then throw it to the upper end of the trough. Repeat till the trough is full. Cover it with wet sacks for two hours.

How to Care for Treated Grain: Spread it out to dry on a clean, or scalded, floor or canvas; when dry, put this clean grain into clean or scalded sacks, and scald out your seeder. Do not smut your clean grain all over again, or your labor is lost. Clean seed produces a clean crop.

OAT SMUT.

(Ustilago avenae Pers.)

Oat smut is very similar to wheat smut. The life history of the fungus which causes this disease is very similar to that of the fungus which causes wheat smut. The fungus enters the young plants soon after germination of the seeds has taken place and grow up with them, finally attacking and destroying the young seeds. By harvest time the grains have been replaced by the fungus, which has already matured its spores. The coats of infected grains are easily broken open and the spores set free. kernels. If this seed is planted a crop of smutted oats will be the result.

To treat the seed to kill the spores no better method is known than the formalin treatment. Make the solution by mixing one pound of formalin with forty-five gallons of water. The seed Many of the spores are set free before harvest time. Some of the spores set free at this time are carried by the wind to the heads of other plants and lodge between the glumes surrounding the kernels. At threshing time many spores also lodge on the may be springled or soaked. Treat the same as explained for wheat smut when the sprinkling method is followed. If the seed is to be soaked the seed can be placed in gunny sacks and placed in a tank containing the formalin solution. The sacks should not be filled more than three-fourths full and should be weighted so that all the seed is submerged. By churning the sacks up and down in the solution the wetting of all the grain is assured. After soaking for about an hour the sacks may be removed and the grain spread out on a clean floor or canvas to dry. The cost of applying the precaution is so light that no field should be sown with seed that is smutted in the least before the same has been treated.

FIGURE XVI—Heads of oat plant, showing loose smut

ROOT ROT OF THE PRUNE.

(Armellaria mellea Vahl.)

The root rot of the prune is caused by a fungus that is commonly known as a toadstool. This fungus occassionally attacks the apple. This toadstool has done a great deal of damage in other sections of the United States. It has evidently been introduced into this section as it does not occur native on any of the wild plants. Another form of toadstool grows on the roots of some wild plants that is somewhat similar to this one. The latter does but little damage to its host, while the former is very injurious.

When prune trees become infested with the root rot fungus they probably do not show signs of the disease for a period of one to three years. The first indications that they are diseased is a yellowing of the leaves, which is sometimes accompanied by a wilting of the same. Trees in this condition may live for a year or more, but they usually die the same season. Sometimes trees that are not infested with root rot show similar characters. If there is any question as to the real cause the disease can be further identified by the presence of the rhizomorphs of th fungus that cling to the bark on the roots and collar. These rhizimorphs are cords of closely adjacent branches of the mycelium. They look very much like the roots of some weeds, from which they can be readily distinguished by cutting them into pieces. They are black on the outside and white within. By tracing the rhizomorphs on the outside of the tree they are found to be continuous with the mycelium within. The outer threads of the rhizomorphs which form the protective covering become white on entering the tree. The strands spread out, becoming fan shaped, and is abundant enough in some cases to form sheet-like layers. That the rhizomorphs are continuous with the mycelium can be demonstrated by removing the bark from the base of the trunk down to the point where the main roots branch off—the point which is most commonly attacked. The mycelium usually shows as a white velvety layer. The decaying wood has a peculiar mushroom odor which also aids much in identification.

Occasionally, during the summer several to many honey colored toadstoods may appear on the base of the trunk of an infested tree. More frequently, however, they do not appear until later in the season and not until the tree is dead.

This root disease, like other diseases of the underground portion of plants, is somewhat difficult to identify. Owing to its nature it is likewise extremely difficult to combat it.

After a tree has once become diseased it can not be cured, and furthermore it is a menace to the neighboring healthy ones. Diseased trees should be grubbed out and burned at once, especially if the toadstools have begun to form at the base. In destroying the tree remove about four feet of each of the main roots, even if they appear perfectly sound. If infested roots are allowed to remain in the ground the mycelium will grow through them for many feet and if these roots come in contact with healthy ones the fungus will grow into the root of the healthy plant and cause its death in the course of time. After a tree has been removed a new one should not be planted in the same place for a period of at least three or four years as the fungus will continue to live in the decaying bits of roots and other vegetable matter for as long a period.

For a detailed account of the disease as it occurs in Prune orchards in the vicinity of Vancouver see Bulletin 59 of this station, written by C. V. Piper and S. W. Fletcher.

FIGURE XVII—A diseased prune tree in a Vancouver orchard, with its base surrounded by mushrooms. These mushrooms are the fruiting organs of the fungus that causes the disease.

FUNGICIDES.

POTASSIUM SULPHIDE SOLUTION.

Potassium sulphide.....1 ounce
Water.....2 gallons

Potassium sulphide is also known as the liver of sulphur. To prepare the solution dissolve the potassium sulphide or liver of sulphur in the proper amount of water and the spray is ready for use.

FORMALIN SOLUTION.

Formalin.....1 pound
Water.....30-45 gallons

Formalin is also called formaldehyde or formalose. It is a 40 per cent. solution of a volatile liquid in water. The 40 per cent. solution is poisonous. Diluted solutions are not poisonous. To prepare a solution pour the formalin in the right amount of water and the fungicide is ready for use. This solution can be used after it has stood for several hours with as equally good results as when first prepared as the formalin volatilizes at about the same rate as the water evaporates with which it is mixed.

COPPER ACETATE SOLUTION.

Copper acetate.....8 ounces
Water.....50 gallons

The copper acetate is completely soluble in water. As soon as the compound is all dissolved the solution is ready for use.

CUPRAM OR AMMONIACAL COPPER CARBONATE.

Copper carbonate.....5 ounces
Ammonia (to test 26° Baume).....3 pints
Water to make.....45 gallons

Make a thin paste of the copper carbonate in about a pint of water. Add ammonia slowly until the compound is all dissolved. The liquid will be a clear deep blue color if the ammonia is of the proper strength. Pour this solution into the water and apply.

BORDEAUX MIXTURE.

Copper sulphate (bluestone).....6 pounds
Quick lime.....4 pounds
Water.....50 gallons

Bordeaux mixture is composed of a number of chemical compounds formed when solutions of bluestone and milk of lime are poured together. The chemical changes which take place are very delicate and in order that they take place correctly the solutions must be dilute and great care exercised in mixing. The method of mixing, as well as using dilute solutions, not only has an important bearing on the chemical but also on the physical nature of the mixture. The most valuable compound formed and the one which is easily modified in the mixing is a blueish, gelatinous substance that has about the same specific gravity as the fluid in which it is suspended. Of the different methods tried the following gave the best results and is the only one recommended.

To prepare the bluestone solution the bluestone can be dissolved very quickly in a small amount of boiling water. Place the bluestone in a wooden vessel and pour the boiling water over it. Pour the strong solution in a barrel and add enough more cold water to make 25 gallons. The solution may also be prepared by placing the bluestone in a closely woven sack that will not lint and suspending the same from a stick laid across the top so that the bluestone hangs just beneath the surface of the water in a well filled barrel. When the bluestone is all dissolved remove the sack and add enough more water to make 25 gallons of bluestone solution.

To prepare the milk of lime place 4 pounds of good quick lime, preferably large pieces, in a wooden vessel. Add enough water to wet it thoroughly. When it begins to dry and crumble add more water. Be careful not to add enough to chill it or too little so that it will burn. When the lime has formed a good paste and is still slaking slowly, allow the slaking to continue and the paste to cool before adding more water. If this method is followed a smooth paste free from grit and small lumps of lime will be obtained provided a good quality of lime has been used. Mix the paste thoroughly with 25 gallons of water.

To mix the solutions of bluestone and milk of lime two men are required to do the work. Pour the two solutions together slowly in such a manner that they mix in falling. If the solutions fall some little distance the churning motion caused by the falling column of water aids in mixing. After the solutions have been

poured together stir the Bordeaux thoroughly using a wide wooden paddle. After straining the mixture is ready for use.

The spray should be tested to see if enough lime has been used to unite with all the bluestone. Fill a shallow dish part full of the Bordeaux mixture and add a few drops of a solution of ferrocyanide of potash (one ounce to ½ pint of water). If a reddish brown color appears add more lime paste and stir thoroughly and test a second time. Continue to add small amounts of lime paste until the reddish brown color fails to appear when the test is made.

When a large quantity of the mixture is needful, mixing is greatly facilitated by preparing stock solutions of both the lime and bluestone. The best mode of preparing these is to fill a barrel partly full of water and suspend in it 100 lbs. bluestone; when this has all dissolved, remove the sack and add enough water to make 50 gallons. You then have a solution in which two pounds of bluestone are dissolved in every gallon of water. Prepare a barrel of the milk of lime in the manner explained for slaking the lime; when this lime solution is stirred thoroughly each gallon of water contains two pounds of lime. To make 50 gallons of the Bordeaux, measure out three gallons of the bluestone solution and add enough water to make 25 gallons. Measure out two gallons of the milk of lime and add water to make 25 gallons. Stir thoroughly, pour the two solutions together, stir, test, and strain, following closely the directions given above.

DOUBLE STRENGTH BORDEAUX MIXTURE.

To prepare double strength Bordeaux mixture use:

Copper sulphate	12 pounds
Quick lime	8 pounds
Water	50 gallons

Prepare the solutions of bluestone and milk of lime and mix as directed above in the preparation of Bordeaux mixture.

THE POWDERY MILDEWS.

The powdery mildews are a group of fungi that take their name from the appearance given the surface of an infested plant. There are sixteen forms growing on various wild and cultivated plants in the state.

In the early growth of the fungus the mycelium and summer spores form a web-like and dusty-whitish surface on the infested portions of the plant on which they are growing. The mycelium branches freely and the branches intertwine and in some cases become so numerous and dense that mat-like patches are formed. The mycelium being external is attached to the host by small sucking organs which penetrate it a very short distance.

Shortly after the mycelium begins to grow summer spores are formed. These spores are borne in chains. They mature at once and drop off and will germinate immediately if conditions are favorable. If these spores come in contact with the host they form a mycelium, attaches itself and soon matures other summer spores. If weather conditions are favorable there may be many crops of summer spores.

Usually late in summer or autumn small round capsule-like bodies make their appearance on the mycelium. They are of a light yellow color at first but later become dark brown or almost black. Inside of each of these capsules is one or more little sacks each of which contain two to eight spores. These are the winter spores. They remain enclosed in these sacks in the capsules until some time the following growing season of the host when they are set free. If they are carried to the host and germination takes place a new mycelium is formed which attaches itself and soon produces one or more crops of summer spores. The disease is thus continued.

The six most important species causing diseases of cultivated plants are:

1. Pea Mildew (Erysiphe polygoni DC.) Pea mildew usually appears rather late in the season after a majority of the plants are nearly mature and as a result causes but little damage. When it does appear early in the season it usually becomes abundant enough to destroy the crop. The leaves, stem and fruit become

covered with a whitish felt-like surface. From a distance the plants appear as if dusted with flour. This mildew also attacks numerous other cultivated plants. It can be held in check by spraying with Bordeaux mixture or cupram or by dusting with flowers of sulphur.

2. Cherry Mildew (Podosphera oxyacanthae DC.) The mildew appears on the leaves of the cherry late in the season, after the fruit is nearly mature. Appearing at such a time of year little injury is done. Should it appear earlier in the season and become abundant it can be combatted by spraying with Bordeaux mixture.

3. Gooseberry Mildew (Sphaerotheca mors-uvae Schw.) This mildew attacks the cultivated gooseberry. It covers the leaves and young twigs and destroys the fruit by covering it with a thick layer of mycelium of a dark brown color. It is quite widely distributed throughout the United States and numerous experimenters have tried various sprays. Potassium sulphide has proven the most efficient. Applications should be made early in the season to protect the young leaves. Two to four applications each season will prevent the disease.

4. Apple Mildew. The identity of this mildew has not been established. It is probably Padosphaera oxyacanthae. It attacks water sprouts, young twigs and leaves. It is most frequently found on nursery stock. It forms a powdery-whitish surface which later becomes a dirty white. When abundant on the leaves it causes them to roll up and occasionally to fall off. This disease can be controlled by the use of either Bordeaux mixture or potassium sulphide.

5. Peach Mildew. The mildew is widely distributed in the peach growing districts. It attacks the leaves, twigs and fruit forming white felt-like patches. The patches on the fruit become dark-brown. The flesh becomes dry and woody and does not make a normal growth. Frequently the fruit splits open exposing the pit. The identity of this mildew has not been fully established. It is probably the same as the apple mildew, or a variety of it.

6. Grape Mildew, Vine Mildew (Uncinula necator Schw.) Grape Mildew has been known as a pest of the vineyard for many years. It is found in nearly every grape growing district in the world. As a rule the fungus forms the powdery whitish surface so characteristic of mildews, on the upper surface of the leaves. It some times attacks and destroys the fruit. European varieties are more susceptible than American varieties. The mildew does not do nearly as much damage in this state as in some others. The amount of damage has not amounted to a great deal. This mil-

dew is combatted by the same method as other mildews. Bordeaux mixture and potassium sulphide have been used in various grape growing districts with greater or less success. Flowers of sulphur applied with a bellows or sprinkled on by hand or in some other convenient way are frequently used. Two or three applications are made. The first should be made two weeks before blooming time, the second at blooming time and the third three or four weeks later. It is held that flowers of sulphur are slowly volatile at a temperature of 80 degrees to 100 degrees F., and that the fumes given off prevent the growth of the summer stage.

7. Mildews on Other Plants—Some of the mildews mentioned above also occur on other cultivated plants than those mentioned. If they become abundant they can be combatted by using any one of the above mentioned sprays or ammoniacal copper carbonate or the flowers of sulphur. A little experimenting will show which one is the most effective.

WHAT TO DO WITH PLANT DISEASE NOT MENTIONED IN THE BULLETIN.

Quite a number of plant diseases occur in the state that are not of enough importance to include in the bulletin but which sometimes do considerable damage locally. If you meet with any of these diseases, and do not know how to combat them, select good specimens of the host that show the effect of the disease. Wrap them up in some convenient manner so that the specimens will keep fresh for a period of several days. Put your name and address on the package. Write a letter telling what you can about the particular trouble and send the letter and specimen to

Botanist, Agricultural Experiment Station,
Pullman, Washington.